SECTION 5.1

FOOD & AGRICULTURE
WINE FERMENTATION

(Updated February 1992)

EMISSION INVENTORY SOURCE CATEGORY
Industrial and Other Processes

EMISSION INVENTORY CODES (CES CODES)AND DESCRIPTION
420-408-6090-0000 (47068) Wine Fermentation

METHODS AND SOURCES

This category is an inventory of the ethanol emissions resulting from the fermentation of grape juice at wineries to produce wine.

During the fermentation process, sugar in the grape juice reacts with yeast to form alcohol (ethanol) and carbon dioxide (CO2) gas. Ethanol is emitted into the atmosphere through evaporation. According to Williams and Boulton, [1] the only important mechanism for ethanol loss is equilibrium evaporation into the escaping CO2 stream. The physical entrainment of ethanol droplets in the CO2 gas is insignificant in modern enclosed fermentation vessels.

Wine production in California was reported in Wines and Vines [2] to be 376,935,000 gallons in 1990. The amount of wine produced in each county was estimated by apportioning the 1990 statewide total according to the amount of grapes crushed and produced in each county.

The California Department of Food and Agriculture [3] (CDFA) annually reports the amount of grapes crushed in each of the 17 grape growing districts in the State (Table I). The amount of grapes crushed in each county (Table II) was estimated by disaggregating the district total crushed according to the proportion of the amount of grapes produced in the county to the district. The data on grape production in each county was taken from the Annual Crop and Livestock Report [4] prepared by each County Agricultural Commissioner's Office. The amount of grapes produced and/or crushed in counties that belong to more than one grape growing district, e.g., Sacramento County, was determined with the aid of CDFA's map[3] (Figure 1) delineating the grape growing districts.

The emission factors used in estimating ethanol emissions during wine fermentation are as follows: white wine - 2.5 lbs ethanol/1000 gallons wine produced, rose wine - 2.9 lbs ethanol/1000 gallons wine produced, and red wine - 6.2 lbs ethanol/1000 gallons wine produced.

The above emission factors were derived by the ARB Stationary Source Division (SSD) staff [5] from a computer model developed by Williams and Boulton. [1] The model simulates the effects of fermentation temperature and the sugar concentration in the fermenting juice on the amount of evaporative ethanol loss during isothermal batch fermentation. Results show that the ethanol loss is proportional to the square of the sugar concentration in the juice and that as fermentation temperature increases, ethanol loss increases exponentially. [1] These researchers reported a good agreement between the estimates of ethanol loss using the model with available experimental measurements.

Using these emission factors and the activity data expressed as gallons of wine produced, ethanol emissions were estimated for the three different types of wine: white, rose and red (Table III). The relative proportion of the three types of wine produced in California were based on a graph showing the percent of total bottled California grape table wine, by color, for 1989. [2] A composite emission factor of 3.037 lb/1000 gal of wine produced was derived by summing the ethanol emissions from the three types of wine and dividing by the total amount of wine production (see sample calculations).

The statewide ethanol emissions for 1990 from wine production are presented by county in Table IV.

ASSUMPTIONS

1. Wine production is proportional to the amount of grapes crushed which can be used to apportion the statewide total wine production to the counties.

2. The amount of grapes crushed is proportional to the amount of grapes produced, which can be used to apportion the district total amount of grapes crushed to the counties.

3. The relative ratios of the red, rose and white wines produced in the State are the same for all counties.

4. The emission factors derived from the Williams and Boulton model are the best available data that represent the amount of evaporative ethanol loss from the fermentation of wine. The major assumptions of this model are: a) the only significant mechanism of ethanol loss during wine fermentation is by evaporation, b) the only variables affecting ethanol loss are fermentation temperature and sugar content of the grape juice, and c) during the fermentation cycle, the tank cooling system is capable of maintaining the desired fermentation temperature at a constant value.

COMMENTS AND RECOMMENDATIONS

The current procedure for estimating ethanol emissions from wine fermentation has the following limitations:

1. The estimated wine production in the county calculated by disaggregating the statewide wine production the counties based on the amount of grapes crushed, may not reasonably reflect the actual wine production in the county. This is because wines fermented in one district maybe made from grapes crushed/produced in another district.

2. The fermentation temperatures used by SSD [5] staff in deriving the emission factors for the different types of wine were based on a 1980 survey of wineries in the San Joaquin Valley. These data may not reflect the actual fermentation temperatures used in wine production in the different wine districts.

A survey of the wine producing districts should be conducted to obtain county specific data on:
a) actual wine production, b) relative ratios of the different types of wine, and
c) fermentation temperatures for the different types of wine.

CHANGES IN METHODOLOGY

There have been no changes in the methodology since 1987.

DIFFERENCES BETWEEN 1987 AND 1990 EMISSION ESTIMATES

The 1990 emission estimates are lower than the 1987 estimates. This is attributed to a lower process rate.

TEMPORAL ACTIVITY

Ethanol emissions are associated with wine fermentation during the grape crushing season, primarily from mid-August through October. During this period, emissions occur 24 hours per day and seven days a week.

SAMPLE CALCULATIONS

A. Calculate statewide ethanol emission for 1990.

1. Determine the process rate (gallons of wine produced)1990 CA wine production = 376,935,000 gallons broken down into: 13% - red, 14% - rose, and 73% - white.

CA red wine production = 376,935,000 gal x .13
= 49,001,550 gal/yr

CA rose wine production = 376,935,000 gal x .14
= 52,770,900 gal/yr

CA white wine production = 376,935,000 gal x .73
= 275,162,550 gal/yr

2. Emission factors in lbs ethanol/1000 gal wine produced: red wine - 6.2, rose wine - 2.9, white wine - 2.5.

3. Emissions = process rate x emission factor/2000 lbs/ton

Red wine emissions = 49,001,550 gal x 6.2 lbs/1000 gal/2000 lbs/ton
= 151.9 tons/yr

Rose wine emissions = 52,770,900 gal x 2.9 lbs/1000 gal/2000 lbs/ton
= 76.52 tons/yr

White wine emissions = 275,162,500 gal x 2.5 lbs/1000 gal/2000 lbs/ton
= 343.95 tons/yr

Total statewide emissions in 1990 = 151.90 + 76.52 + 343.95
= 572.37 tons/yr

B. Calculate composite emission factor.

statewide emissions x 2000 lbs/ton /statewide gal of wine produced

572.37 tons x 2000 lbs/ton /376,935,000 gal = 3.037 lbs ethanol/1000 gal wine produced

C. Estimate the 1990 ethanol emissions in Alameda County.

1. Determine the process rate (gal of wine produced) in Alameda.

A) First, estimate the amount of grapes crushed in Alameda. Alameda is one of the 6 counties that comprise District 6 with a total amount of grapes crushed in 1990 of

8978.4 tons. Calculate Alameda's share of the district's total amount of grapes crushed based on the amount of grapes produced.

$$\frac{\text{4629 tons grapes produced in ALA}}{\text{9680 tons grapes produced in District 6}} \times \text{8978.4 tons grapes crushed in District 6}$$

= 4293.49 tons grapes crushed in Alameda

B) Estimate the amount of wine produce in Alameda.

$$\frac{\text{4,293 tons grapes crushed in ALA}}{\text{2,576,005 tons grapes crushed in CA}} \times \text{376,935,000 gal of CA wine produced}$$

= 628,246.71 gal wine produced in ALA

2. Use composite emission factor of 3.037 lbs ethanol/1000 gal of wine produced.

3. Process rate x emission factor = 1990 ethanol emissions in Alameda

628,246.71 gal wine x 3.037 lbs/1,000 gal/2,000 lbs/ton

= 0.95 tons/yr

REFERENCES

1. L.A. Williams & R. Boulton. Modeling and Prediction of Evaporative Ethanol Loss During Wine Fermentation, American Journal of Enology and Viticulture, 32:234-242, (1983).

2. "The 48th Annual Statistical Survey", Wines and Vines, pgs 16-43, (July 1991).

3. California Department of Food and Agriculture (CDFA), Final Grape Crush Report 1990 Crop, (March 11, 1991).

4. County Agricultural Commissioner's Office, 1990 Agricultural Crop and Livestock Report, California, (1988).

5. Air Resources Board, A Suggested Control Measure for Control of Ethanol Emissions from Winery Fermentation Tanks, a Technical Support Document Prepared by the Energy Section, Stationary Source Division, ARB, California, (October 1991).

UPDATED BY

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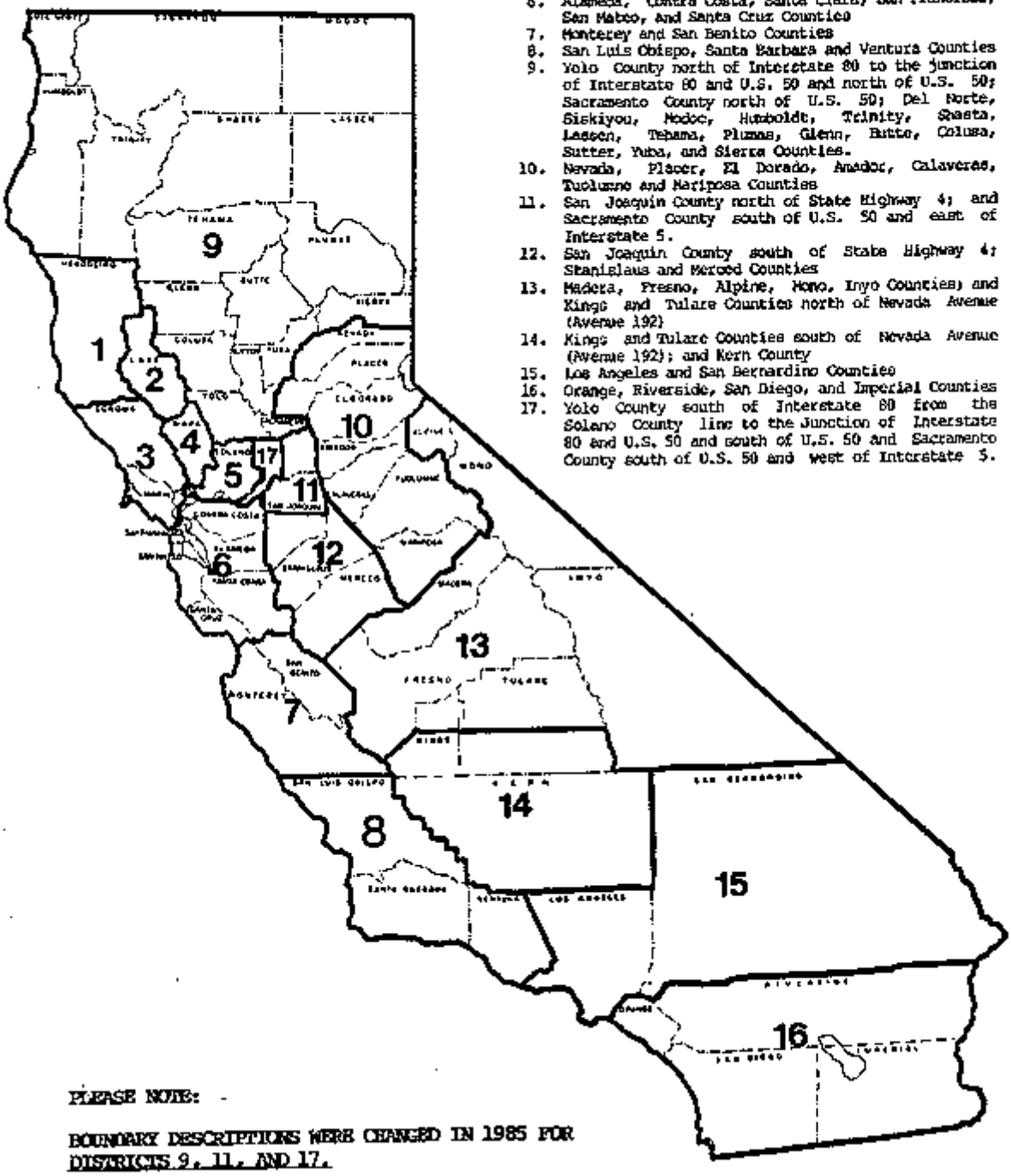
MAP & DEFINITIONS OF CALIFORNIA GRAPE PRICING DISTRICTS



1. Mendocino County
2. Lake County
3. Sonoma and Marin Counties
4. Napa County
5. Solano County
6. Alameda, Contra Costa, Santa Clara, San Francisco, San Mateo, and Santa Cruz Counties
7. Monterey and San Benito Counties
8. San Luis Obispo, Santa Barbara and Ventura Counties
9. Yolo County north of Interstate 80 to the junction of Interstate 80 and U.S. 50 and north of U.S. 50; Sacramento County north of U.S. 50; Del Norte, Siskiyou, Modoc, Humboldt, Trinity, Shasta, Lassen, Tehama, Plumas, Glenn, Butte, Colusa, Sutter, Yuba, and Sierra Counties.
10. Nevada, Placer, El Dorado, Amador, Calaveras, Tuolumne and Mariposa Counties
11. San Joaquin County north of State Highway 4; and Sacramento County south of U.S. 50 and east of Interstate 5.
12. San Joaquin County south of State Highway 4; Stanislaus and Merced Counties
13. Madera, Fresno, Alpine, Mono, Inyo Counties; and Kings and Tulare Counties north of Nevada Avenue (Avenue 192)
14. Kings and Tulare Counties south of Nevada Avenue (Avenue 192); and Kern County
15. Los Angeles and San Bernardino Counties
16. Orange, Riverside, San Diego, and Imperial Counties
17. Yolo County south of Interstate 80 from the Solano County line to the Junction of Interstate 80 and U.S. 50 and south of U.S. 50 and Sacramento County south of U.S. 50 and west of Interstate 5.

PLEASE NOTE:

BOUNDARY DESCRIPTIONS WERE CHANGED IN 1985 FOR DISTRICTS 9, 11, AND 17.

TABLE I
1990 AMOUNT OF GRAPES CRUSHED IN CALIFORNIA BY DISTRICT [a]

DISTRICT [b]	GRAPES CRUSHED (TONS/YR)
1	39,778.9
2	7,710.7
3	111,930.1
4	114,303.7
5	6,094.2
6	8,978.4
7	105,080.0
8	61,546.9
9	17,880.8
10	8,694.4
11	286,441.7
12	325,379.3
13	1,007,494.3
14	448,029.1
15	2,633.0
16	9,309.2
17	14,720.2
STATE TOTAL	2,576,005.0

a. Abstracted from Reference 3.
b. Grape growing districts are shown in Figure 1, Reference 3.

Table II

1990 Grapes Crushed (Tons) in California by Counties

County Name	Air Basin	Grapes Crushed
ALAMEDA	SF	4293.49
ALPINE	GBF	0
AMADOR	MC	5155.79
BUTTE	SV	0
CALAVERAS	MC	328.94
COLUSA	SV	0
CONTRA COSTA	SF	1975.62
DEL NORTE	NC	0
EL DORADO	SV	2416.63
EL DORADO	LT	0
FRESNO	SJV	675783.97
GLENN	SV	0
HUMBOLDT	NC	0
IMPERIAL	SED	0
INYO	GBV	0
KERN	SED	0
KERN	SJV	305423.06
KINGS	SJV	16358.86
LAKE	LC	7991.00
LASSEN	NEP	0
LOS ANGELES	SC	0
LOS ANGELES	SED	0
MADERA	SJV	242734.07
MARIN	SF	0
MARIPOSA	MC	85.88
MENDOCINO	NC	39778.80
MERCED	SJV	90453.69
MODOC	NEP	0
MONO	GBV	0
MONTEREY	NCC	98606.44
NAPA	SF	114303.70
NEVADA	MC	481.50
ORANGE	SC	0
PLACER	LT	0
PLACER	MC	0
PLACER	SV	225.57
PLUMAS	MC	0
RIVERSIDE	SED	0
RIVERSIDE	SC	9272.43
SACRAMENTO	SV	57954.27
SAN BENITO	NCC	6473.53
SAN BERNARDINO	SC	2633.00
SAN BERNARDINO	SED	0
SAN DIEGO	SD	36.77
SAN FRANCISCO	SF	0
SAN JOAQUIN	SJV	379637.58
SAN LUIS OBISPO	SCC	33179.62
SAN MATEO	SF	0
SANTA BARBARA	SCC	28367.28
SANTA CLARA	SF	3594.14
SANTA CRUZ	NCC	222.60
SHASTA	SV	0
SIERRA	MC	0
SISKIYOU	NEP	0
SOLANO	SF	6094.30
SOLANO	SV	0
SONOMA	NC	55965.05
SONOMA	SF	55965.05
STANISLAUS	SJV	114505.25
SUTTER	SV	0
TEHAMA	SV	0
TRINITY	NC	0
TULARE	SJV	219145.76
TUOLUMNE	MC	0
VENTURA	SCC	0
YOLO	SV	29436.68
YUBA	SV	0
TOTAL		2608880.44

TABLE III

1990 CALIFORNIA WINE PRODUCTION AND EMISSION ESTIMATE

WINE TYPE	WINE PRODUCED [a]	EMISSION FACTOR [b]	ETHANOL EMISSION
RED	49,001,550	6.2	151.90
ROSE	52,770,990	2.9	76.52
WHITE	275,162,550	2.5	343.95
TOTAL	376,935,000		572.37

a. Reference 2
b. Reference 1 and 5

Table IV
1990 Area Source Emissions
Activity:Wines & Brandy
Process: Food & Agricultual
Entrainment: Process Loss
Dimn: Fermentation (Wine) Wine
CES: 47068
Process Rate Unit: 1000 Gallons Produced

AB	County	Process Rate	TOG Emis. (Tons / Year)	CO Emis. (Tons / Year)	NOX Emis. (Tons / Year)	SOX Emis. (Tons / Year)	PM Emis. (Tons / Year)
LC	LAKE	628	1.78	0.00	0.00	0.00	0.00
MC	AMADOR	754	1.15	0.00	0.00	0.00	0.00
	CALAVERAS	48	0.07	0.00	0.00	0.00	0.00
	MARIPOSA	13	0.02	0.00	0.00	0.00	0.00
	NEVADA	71	0.11	0.00	0.00	0.00	0.00
NC	MENDOCINO	5821	8.84	0.00	0.00	0.00	0.00
	SONOMA	16378	24.87	0.00	0.00	0.00	0.00
NCC	MONTEREY	14429	21.91	0.00	0.00	0.00	0.00
	SAN BENITO	947	1.44	0.00	0.00	0.00	0.00
	SANTA CRUZ	526	0.05	0.00	0.00	0.00	0.00
SC	SAN BERNARDINO	385	0.59	0.00	0.00	0.00	0.00
SCC	SAN LUIS OBISPO	4855	7.37	0.00	0.00	0.00	0.00
	SANTA BARBARA	4151	6.30	0.00	0.00	0.00	0.00
SD	SAN DIEGO	5	0.10	0.00	0.00	0.00	0.00
SED	RIVERSIDE	1357	2.06	0.00	0.00	0.00	0.00
SF	ALAMEDA	628	0.95	0.00	0.00	0.00	0.00
	CONTRA COSTA	289	0.44	0.00	0.00	0.00	0.00
	NAPA	16726	25.40	0.00	0.00	0.00	0.00
	SANTA CLARA	526	0.80	0.00	0.00	0.00	0.00
	SOLANO	8918	1.35	0.00	0.00	0.00	0.00
	SONOMA	16378	24.87	0.00	0.00	0.00	0.00
SJV	FRESNO	98884	150.16	0.00	0.00	0.00	0.00
	KERN	44691	67.86	0.00	0.00	0.00	0.00
	KINGS	2394	3.63	0.00	0.00	0.00	0.00
	MADERA	35518	53.93	0.00	0.00	0.00	0.00
	MERCED	13236	20.10	0.00	0.00	0.00	0.00
	SAN JOAQUIN	55550	86.36	0.00	0.00	0.00	0.00
	STANISLAUS	16755	25.44	0.00	0.00	0.00	0.00
	TULARE	32067	28.69	0.00	0.00	0.00	0.00
SV	EL DORADO	354	0.54	0.00	0.00	0.00	0.00
	PLACER	33	0.05	0.00	0.00	0.00	0.00
	SACRAMENTO	8480	12.88	0.00	0.00	0.00	0.00
	SOLANO	892	1.35	0.00	0.00	0.00	0.00
	YOLO	4307	6.54	0.00	0.00	0.00	0.00
TOTAL		406994	588.00	0.00	0.00	0.00	0.00

Fraction of Reactive Organic Gases (FROG): 1.0000
(Reactive Organic Gases (ROG) Emissions = TOG X FROG)
Fraction of PM10 (FRPM10): .7000
(PM10 Emissions = PM X FRPM10)